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The EJSE is a transportable system for exercising and monitoring participants in a JTIDS communications network. The algorithms described are designed for use in the EJSE architecture. The intent was to prove the feasibility of using JTIDS as the ATALARS data link by demonstrating the use of ATC algorithms in the closed-simulation environment of the EJSE. To this end, this report describes the design and implementation of these ATC algorithms in the EJSE and upgrades to the EJSE.

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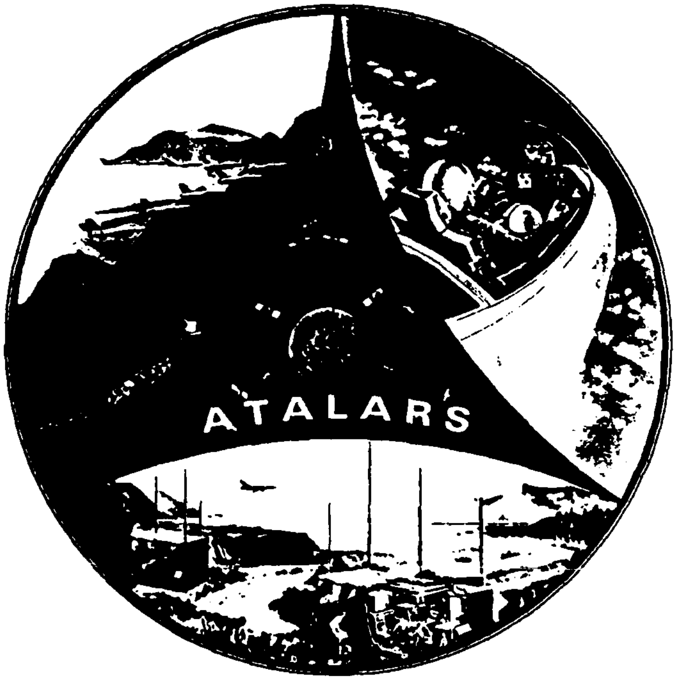

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1.0 Scope

1.1 Identification. This report is the final report discussing the Automated Tactical Aircraft Launch and Recovery System (ATALARS) upgrades to the Enhanced Joint Tactical Information Distribution System (JTIDS) System Exerciser (EJSE) as well as recommendations for future Air Traffic Control (ATC) study. This report is prepared under contract F19628-87-C-0254, and in accordance with the guidelines contained in DI-S-3591/A.

Hereinafter, the EJSE and its components refer to the Army and Navy Configured EJSE baseline developed under contract number DAAB07-87-C-A043. The Display Group (DG) portion of EJSE, serving as a model for the ATALARS Ground Control Unit (GCU) is hereinafter referred to as tne GCU. The Interactive Simulation Group (ISG) portion is hereinafter referred to as the ISG.

1.2 Purpose. The EJSE is a transportable system for exercising and monitoring participants in a JTIDS communications network. The algorithms described are designed for use in the EJSE architecture. The intent was to prove the feasibility of using JTIDS as the ATALARS data link by demonstrating the use of ATC algorithms in the closed-simulation environment of the EJSE. To this end, this report describes the design and implementation of these ATC algorithms in the EJSE and upgrades to the EJSE.

The modifications to the EJSE described in this report were designed and developed in support of the ATALARS Proof of Concept demonstration being developed under contract F19628-87-C-0254, which constitutes Phase II of a Small Business Innovation Research (SBIR) contract resulting from Solicitation No. AF87- 032.

The Ground Control Unit Computer Program (GCUCP) is the upgrade to the Display Group (DG) of the EJSE to support the ATALARS Proof of Concept demonstration. The purpose of the GCUCP was to model an ATALARS Ground Control Unit that implements ATC algorithms which identify and resolve ATC problems in a military and civil airspace environment and provide resolution directives via JTIDS messages transmitted over a JTIDS data link.

For this study, the GCUCP demonstrated the feasibility of using JTIDS as the ATALARS data link through participation in ATALARS scenarios conducted in the closed simulation environment of the EJSE.

The Interactive Simulation Group Computer Program (ISGCP) provided the closed simulation environment needed to produce simulated elements and create conditions of path divergence, separation violation, and diversion. The ATC algorithms residing in the GCUCP resolve the violations and send corrective action to the ISGCP which in turn responds by altering the simulated elements accordingly.

1.3 Introduction. The upgrades described in this report were designed and developed in support of the ATALARS Proof of Concept demonstration being developed under the above mentioned contract. They use accepted methodologies implemented in current ATC problem resolution during military/civil airspace management. Their design was strictly tailored to the EJSE architecture with consideration of its Central Processing Unit (CPU) capabilities and memory. The simplifying assumptions as described herein are consistent with the scope of the current contract.

In general, the EJSE employed advanced ATC algorithms and a dynamic scenario database to demonstrate how JTIDS could be used to manage ATC problems in a military and civil environment. Through implementation of the Phase II ATC Algorithms, the EJSE resolved problems regarding:

a. Path Conformance

b. Separation Assurance

c. Diversion

Missed Approach, although described in the Phase II proposal, was deleted from the Phase II demonstration due to the processing burden required by the more frequent transmissions and processing of the Close Control and Landing messages offered through JTIDS. As such, the Phase II demonstration depicted aircraft under ATALARS control up to the Initial Approach Point (IAP) of their destination airbase, at which point the ATALARS GCU generated a JTIDS handover message to relinquish control of the aircraft to an arrival controller.

The ATC problems described above are detected and resolved through the following set of ATC Algorithms:

a. Path Conformance Alert (PCA)

b. Flight Path Generation (FPG)

c. Conflict Avoidance (CA)

d. Hazard Alert (HA)

e. Hazard Resolution (HR)

f. Diversion (DIV)

Table I presents a cross reference matrix of ATC Algorithms to ATC Problems. A description of each of these algorithms is contained in Section 3.0 of this report.

TABLE I

ATC ALGORITHMS TO ATC PROBLEMS CROSS REFERENCE MATRIX

ATC PROBLEMS / ATC ALGORITHMS	PATH CONFORMANCE	SEPARATION ASSURANCE	DIVERSION
PATH CONFORMANCE ALERT	X		
HAZARD ALERT		X	
HAZARD RESOLUTION		X	
FLIGHT PATH GENERATION	X	X	X
CONFLICT AVOIDANCE	X	X	X
DIVERSION			X

The ATC algorithms are totally contained within the GCU component of the EJSE and are written in the FORTRAN 77. The ISG is present in the EJSE to simulate elements in the ATALARS control area which can acknowledge and react to ATC directions resulting from the GCU algorithms. The design and description of the ISG and non-algorithmic functions of the GCU are contained in Interim Technical Reports 1, 2, & 3 submitted earlier under this contract.

In general, the GCUCP upgrade was comprised of ATC Algorithms, automated JTIDS message capability and associated databases. A complete GCUCP base line is contained in the Computer Program Product Specification of the Display Processor Computer Program of the Army/Navy-Configured EJSE, W80YBY87C3003, Type C5.

The ISGCP upgrade was comprised of the transformation of the Simulation Tape Generation Program (STGCP) from an off-line, non-real program into a real-time, on-line program which simulates and reacts to ATC problems at the GCUCP. A complete identification of the baseline STGCP in contained in the Computer Program Product Specification of the Simulation Tape Generation Computer Program of the Army/Navy-Configured EJSE, W80YBY87C3001, Type C5.

1.4 Organization and Content. This report is structured as follows:

a. Section 1.0 provides a scope of the report

b. Section 2.0 identifies the referenced documents in support of this report

c. Section 3.0 is a description of each ATC algorithm employed in the EJSE and a description of the database showing the structure and interrelationship of data base tables in the EJSE

d. Section 4.0 is the description of the new/modified functions applicable to the ISG

e. Section 5.0 provides the results and recommendations

f. Section 6.0 a list of acronyms used in this report

g. Section 7.0 is a glossary of ATC definitions as they pertain to this report.

2.0 REFERENCED DOCUMENTS

Contract F19628-87-C-0254 CDRL Sequence No. 403	19 April 1989	ATALARS Air Traffic Control Algorithm for the Phase II Proof of Concept Demonstration Interim Technical Report 1.
Contract F19628-87-C-0254 CDRL Sequence No. 405	2 November 1989	ATALARS Data Base Design for the ATC Algorithms of the ATALARS EJSE Interim Technical Report 2.
Contract F19628-87-C-0254 CDRL Sequence No. 409	22 November 1989	Interaction Simulation Group for the ATC Algorithms of the ATALARS EJSE Interim Technical Report 3.
W80YBY87C3003	7 April 1989	Display Processor Computer Program of the Army Configured EJSE and the Navy Configured EJSE, Type C5 (Draft).
W80YBY87C3001	7 April 1989	Simulation Tape Generation Computer Program of the Army Configured EJSE and the Navy Configured EJSE, Type C5 (Draft).
	1 January 1986	JINTACCS JTIDS TIDP (Test Edition REV1: Volume II - Interface Specifications, Fixed Word Format (Part 1 through 4) (U).
	15 June 1981	JINTACCS JTIDS TIDP (Test Edition): Annex A - Minimum Implementation (U).
	July 1986	JINTACCS JTIDS Technical Interface Design Plan - Test Edition (TIDP - TE), Revision 1, Change 1.
	December 1986	US Air Force TIDP Interim Change Notice Package for the following ICPs*:

ICP	ICP	ICP	ICP
32.4	164.2	193.1	203.1
34.1	167.3	194.2	204.1
44.2	169.1	195.1	206.1
97.2	171.1	197.0	207.2
127.3	172.2	200.1	209.3
138.3	176.2	200.1	212.1
162.2	179.4	202.1	258.2

* Number after decimal point is the change number of the ICP.

3.0 ALGORITHMS AND DATABASE ITEMS.

Descriptions of the automated ATC algorithms employed in ACSI's Phase II Proof of Concept Demonstration for ATALARS are contained in the subparagraphs that follow (Refer to section 7.0 for ATC definitions). The thresholds which invoke path conformance and separation assurance violations are operational parameters of the GCU system. The thresholds stated in this report are the preset values listed in Table II. They may be changed, however, before or during an ATALARS scenario. FORTRAN 77-defined variables are in upper case throughout this report, e.g. SAPTPCAL.

The database items associated with the algorithms consist of activation switches and threshold parameters. A full listing of the variables along with their limits is listed in Table III.

3.1 Path Conformance Alert (PCA) Algorithm. PCA is a periodic task that continually monitors each ATALARS controlled aircraft within the ATALARS control area. If an aircraft deviates from its flight plan by more than SAPTPCAL feet in altitude or by more than SAPTPCRG nautical miles laterally, a non conformance alert is displayed and PCA requests the FPG algorithm to resolve the non conformity by generating a new flight plan.

TABLE II

ATALARS OPERATIONAL PARAMETERS

ATC PROBLEM	OPERATIONAL PARAMETER	PRESET CRITERIA OR VALUE
Path Conformance	Altitude	300 feet
	Lateral Range	2 nautical miles
	Active Switch	ON
	Monitor Rate	30 seconds
Conflict Avoidance	Altitude	Message Value
	Lateral Range	Threat Dependent
	Active Switch	ON
Separation Assurance	Altitude	500 feet
	Lateral Range	3 nautical miles
	Active Switch	ON

TABLE III

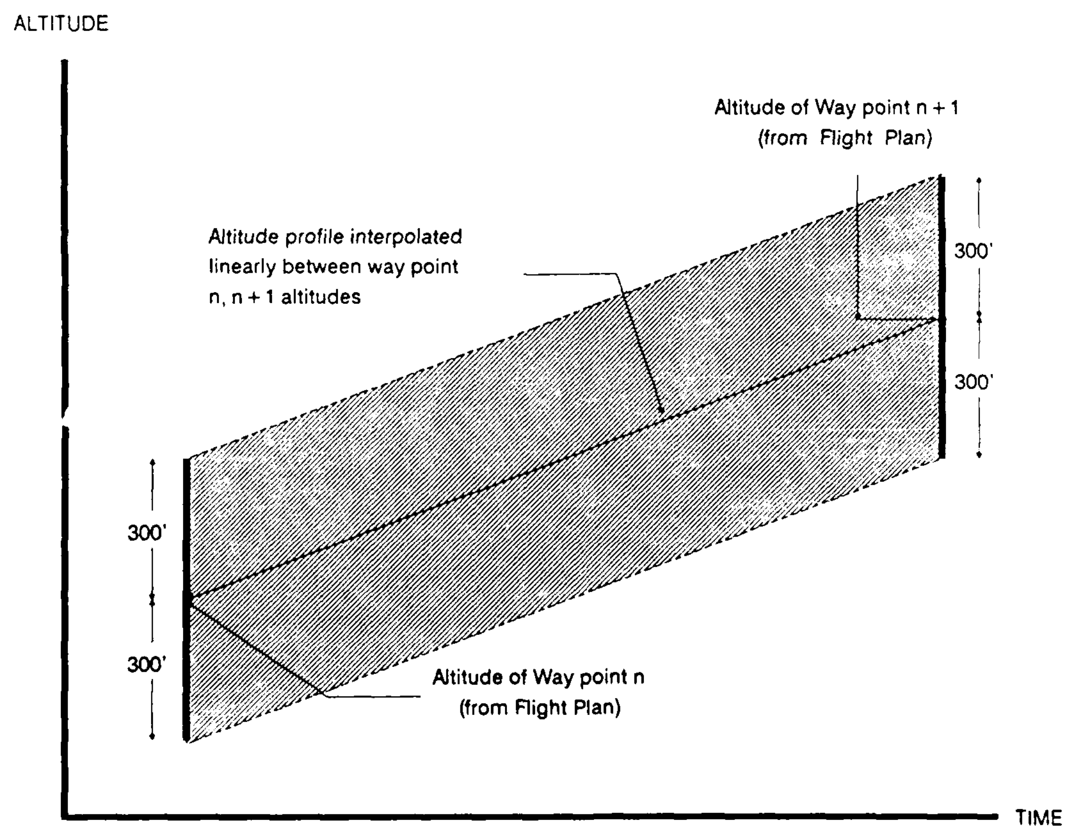
ATALARS OPERATIONAL PARAMETER VALUES

PARAMETER	DEFAULT	VALID RANGES
SAPTPCAL	300'	100' - 5000'
SAPTPCRG	2nm	2nm - 10 nm
SAPTPCIN	ON = 1	0 - 1
SAPTPCRT	30 secs	15 secs - 180 secs
SAPTCFIN	ON = 1	0 - 1
SAPTHZAL	500'	500' - 5000'
SAPTHZRG	3nm	2nm - 10nm
SAPTSAIN	ON = 1	0 - 1
SAPTAEN	ON = 1	0 - 1

The PCA is enabled for each ATALARS aircraft every SAPTPCRT seconds if the operator has enabled (=ON) the Path Conformance Indicator (SAPTPCIN). The default values for SAPTPCAL is 300 feet, SAPTPCRG is 2 miles, and SAPTPCRT is 30 seconds and are modifiable by the operator at the GCUCP. The flight path of an aircraft under ATALARS control is considered in violation if its deviation exceeds any of these limits. The time to perform path conformance is contained in a Path Conformance monitor table. This table contains an entry for each aircraft. The periodic processor function of the GCU examines the table periodically (at least every second). When a time to perform path conformance is reached, the PCA algorithm is invoked. PCA uses the altitude, latitude, longitude and time from the current location and identity for that particular element message. If the message time coincides with a waypoint time in the aircraft's flight plan table, then the altitude, latitude and longitude of the waypoint are used in the check. Otherwise the values of altitude, latitude and longitude used in the check are linearly interpolated form the values of these

parameters at the waypoints whose time immediately precedes and follows the message time. In either case, the values of the parameters obtained from the flight plan table are its "assigned" values. (See figure 1) The aircraft's altitude must be within SAPTPCAL feet of its assigned altitude; the aircraft's lateral position must be within a SAPTPCRG nautical mile radius of its assigned position. If path conformance is not met, the FPG algorithm is called. Path conformance for this aircraft will be suspended while path deviation is being resolved.

3.2 Flight Path Generation (FPG) Algorithm. When invoked as a resolution to a Path Conformance violation, Diversion or Separation Assurance, FPG generates a conflict free path (if SAPTCFIN, Conflict Avoidance Indicator, is enabled (=ON)) and a hazard free path for the first thirty seconds of the new flight path (if SAPTSAIN, Separation Assurance Indicator is enabled (=ON)).



Shaded area is altitude conformance area
for time between way points n, n + 1

Figure 1. Altitude Conformance Envelope

a. The assumptions used in the algorithm are as follows:

1) The flight path of an aircraft will consist of a series of straight line segments joining projected waypoints.

2) On each line segment, any changes in the aircraft's latitude and longitude will be linear with respect to time. In our ATALARS demonstration, the ground speed will be constant along each line segment.

3) Magnitude of jump discontinuities in ground speed at waypoints will be small.

4) Any changes in the aircraft's altitude will be linear with respect to time along each segment. Changes in this rate at waypoints will be instantaneous, however, they will not exceed 4000 feet per minute in magnitude. The climb/descent profile is determined by the difference between waypoint altitudes divided by the elapsed time.

b. The FPG Algorithm operates in three phases:

1) Phase 1

The current position of the aircraft is extrapolated 4 seconds into the future. It is assumed that the aircraft will continue to travel at a constant accelerationdeceleration rate, its course of travel will not change, and the aircraft's altitude climb/descent rate will not change. This point will become a new waypoint in the flight plan. The aircraft will continue to travel through all remaining waypoints to the IAP with the only change at each waypoint being the time to reach each respective waypoint.

2) Phase 2

If the Conflict Avoidance Indicator (SAPTCFIN) is enabled (= ON), the newly generated path described above is checked to assure that the path is conflict free to its IAP. If it is not conflict free, additional waypoints are inserted to the flight plan and waypoint times are recalculated. See Section 3.3 for more details.

3) Phase 3

If the Separation Assurance Indicator (SAPTSAIN) is enabled (= ON), the newly generated path described in Phases 1 and 2

is checked to be hazard free for the first thirty seconds of its new path. If the newly generated path is not hazard free, additional waypoints are inserted into the flight path to resolve the hazard situation. See Sections 3.4 and 3.5 for more details.

In the instances the Conflict Avoidance Indicator (SAPTSAIN) and the Separation Assurance Indicator (SAPTSAIN) are enabled, Phases 2 and 3 are continually checked until the pass through the two checks produces no new waypoints. At this time the flight path is both conflict free (to its IAP) and hazard free (for thirty seconds).

3.3 Conflict Avoidance (CA) Algorithm. CA is called by FPG algorithm to determine when a generated path conflicts with a restricted fixed airspace. The new path is generated in such a way that the aircraft will not penetrate the restricted airspace. The volume of restricted fixed airspace is defined to be a cylindrical area around a land point/track with the lateral range being ten or twenty miles, depending on threat type with the vertical range being from ground level (0 ft. msl) to the elevation in the land point/track message.

If the aircraft's flight plan enters any restricted area, the aircraft must be rerouted laterally to avoid the restricted area. Additional waypoints are inserted into the flight plan to route the aircraft around the area and the new path chosen will be one with minimum distance laterally to be traveled by aircraft. It should be noted that an aircraft whose flight plan calls for the aircraft to fly at an altitude that is greater than the ceiling of the restricted airspace is not in conflict with the airspace.

The GCU is equipped to place the conflict circles around the landpoint/tracks on the Graphic Display Terminal (GDT) by a single enabling switch action.

It should also be noted that the Conflict Avoidance algorithms are only triggered upon the generation of a new flight path with the Conflict Avoidance indicator enabled. If the conflict avoidance indicator is enabled after the generation of a new path in which a conflict occurs, the aircraft will continue to travel through the restricted airspace unless FPG is called (by either Path Conformance, Hazard Alert, or Diversion Alert). Thus, a generated path is assumed conflict free.

3.4 Hazard Alert (HA) Algorithm. HA is an event driven task that extrapolates the position of each aircraft that is being reported on the JTIDS network for a potential violation of airspace. HA provides an entry to a HA table when any two aircraft are within hazardous range. The simultaneous occurrence of the following is termed "within hazardous range":

a) Ground plane projections of flight parth are within SAPTHZRG nautical miles of each other, and

b) Altitudes differ by less than SAPTHZAL feet.

The aircraft's flight path is linearly extrapolated from its last reported position and velocity. The default values for SAPTHZRG is 3 miles and for SAPTHZAL is 500 feet. The hazard alert will only be triggered if the separation assurance indicator is enabled (SAPTSAIN = ON).

HA is performed by extrapolating the position of each aircraft thirty seconds into the future. An aircraft with a filed flight plan is assumed to be following its flight plan and all other aircraft will be extrapolated using their current headings and with altitudes that remain constant. Upon extrapolation of each aircraft's position, each pair of aircraft with at least one aircraft under ATALARS control will be compared to determine if a hazard (violation on each aircraft's airspace) will occur 30 seconds into the future. If the violation does exist, an entry is filed for Hazard Resolution.

The HA Algorithms are involved by a periodic process in the GCU once a second. HA has been designed to provide frequent pairwise monitoring of many aircraft without imposing a heavy computational load on the GCU during the Hazard Resolution process.

HA is also performed on aircraft having a new flight path being generated and aircraft initially placed under ATALARS control. In these situations, the HA algorithms are performed with an extrapolation of aircraft position for each second into the future up to a period of 30 seconds. Those algorithms are modified for this application to further reduce the computational load on the GCU.

3.5 Hazard Resolution (HR) Algorithm. HR is scheduled by the HA algorithm. In conjunction with the FPG algorithm, it generates hazard-free flight plans for the ATALARS aircraft involved in a hazard alert condition.

HR resolves an HA for an aircraft under ATALARS control by generating a new flight path for the aircraft. The destination IAP will remain the same as it was before the alert. The first segment of the path will be generated within the routine. The remaining portion will be generated by FPG. HR issues an alert only when a hazard condition detected between ATALARS-controlled aircraft has been resolved.

HR generates a new flight plan designed to avoid a collision between the two aircraft detected by the HA Algorithm. The two aircraft will be separated by altitude equal to twice the hazard threshold (SAPTHZAL). For example, if the hazard threshold is 500 feet, the two aircraft will be separated by 1000 feet. The rules for separating the two aircraft will be as follows:

a) If both aircraft are under ATALARS control, the aircraft traveling at a lower altitude will descend to the desired "safe" altitude

b) If either of the aircraft mentioned in 1 (i.e. both under ATALARS control) are in an emergency situation (as detected by the JTIDS message), the aircraft under the emergency condition will have priority

and the other aircraft will be forced to climb to a "safe" altitude (if he was traveling at an altitude above the emergency aircraft) or descend to a "safe" altitude (if he was traveling at an altitude below the emergency aircraft). If both aircraft are in an emergency situation, the rules described in 1 apply.

3) If an ATALARS controlled aircraft is in conflict with either a non-ATALARS aircraft or an aircraft not yet under ATALARS control, the ATALARS controlled aircraft will either climb or descend to a "safe" altitude. The GCU cannot redirect an aircraft over which it does not have control.

With the above rules intact, the aircraft will be redirected to avoid the hazardous area and will continue along through all of its remaining waypoints to the IAP. This is done by calling the FPG algorithm.

3.6 Diversion (DIV) Algorithm. DIV determines a new destination airbase for any ATALARS aircraft whose filed destination has been closed. DIV is enabled whenever an airbase status is changed from open to closed. The status is monitored by the GCU net message input processing function. When a message is received by the GCU indicating that a given base has been closed, DIV is called to divert aircraft to an alternate airbase.

DIV searches the airbase table for ATALARS-controlled aircraft scheduled to land at the closed base. The aircraft are prioritized according to their Estimated Time of Arrivals (ETAs), with the one have the earliest ETA given highest priority. For each of these aircraft to be diverted, the DIV algorithm will assign, as its new destination, the closest open airbase to the aircraft at the time the airbase was closed. The GCU will pass to the FPG algorithm the location of the new airbase as the IAP and the FPG will generate a path to this new point, calling the HA and CA algorithms as requested by the operator (SAPTSAIN and SAPTCFIN enabled).

The assumptions taken by the algorithms are that each aircraft has sufficient fuel to reach any open airbase to which the aircraft has been routed and the runway lengths at each airbase satisfy the requirements of each aircraft that is routed to that airbase.

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4.0 BRIEF DESCRIPTION OF STGCP UPGRADE TO ISGCP

The following paragraphs describe the major STGCP functional areas modified and the functions added to the STGCP to transform it into the ISGCP with simulation capabilities needed to create, control, and modify the simulated environment for the Phase II Proof of Concept Demonstration.

Figure 2 provides a description of the upgrades to the STGCP and the Display Processor Computer Program (DPCP) to generate the ISGCP and the GCUCP respectively. The ISGCP provides both an off-line and on-line environment.

4.1 On-Line Processing. The ISGCP has the capability to communicate with the GCUCP over an Ethernet local area network (LAN). The ISGCP sends status, JTIDS, and flight plan messages to the GCUCP and receives JTIDS messages from the GCUCP.

4.2 Real-Time Processing. The ISGCP has the capability of performing its processing according to scheduled times. A built-in one second granularity clock is used to trigger time-dependent processing.

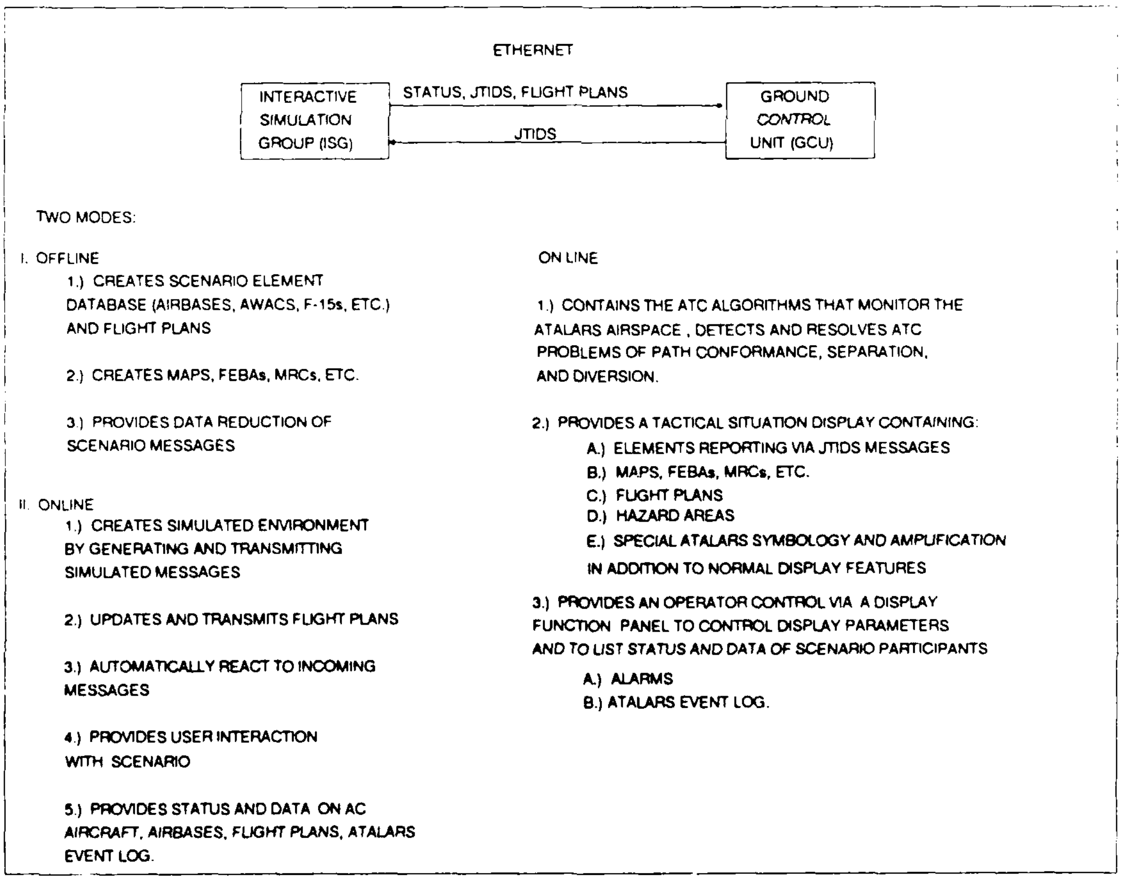

Figure 2. ATALARS/EJSE Software Functional Diagram

4.3 Automatic Message Processing. The ISGCP has the capability of automatically generating outgoing messages and automatically processing incoming messages. Table IV contains the messages that are automatically processed by the ISGCP.

4.4 Flight Plan Generation. The ISGCP has the capability of creating a flight plan entry in the flight plan table based upon an Air PPLI message. It then automatically creates and transmits flight plan messages from the table entry to the GCUCP. The flight plan entry values are obtained from the simulator's database tables which are created from the user's input specification file. The input specification file is a static disk file that can be altered to prove the ATALARS concept.

4.5 Dynamic Data Base Update. The ISGCP has the capability to dynamically update its database tables based upon an operator input request or upon receipt of newly generated waypoints received by the GCUCP on an ATALARS-controlled aircraft.

4.6 Interactive Capability. The ISGCP permits the operator to interact with the scenario. The operator can change the heading, altitude, and/or speed of any non command and control type Air PPLI's. (These are the aircraft that will come under ATALARS control at some point during the scenario.) The operator has the capability to close any open airbase. The operator also has the capability to stop, or go (resume)/idle (freeze) the scenario and to change the time that the ISGCP will cease processing. This will be the main driver for triggering the algorithms described in Section 3.0.

4.7 Menu Driven Keyboard-Printer(KP). The ISGCP contains a series of menus and screens arranged in top-down sequence. These present choices to the operator by guiding him through the possibilities of interaction with the scenario or offering the status of the scenario.

4.8 Data Dictionary Capability. The ISGCP contains the capability of obtaining static data from a disk file which has been correlated to JTIDS-message field data. Specifically, the capability is being used to obtain the ASCII description of the airbases correlated to the voice callsign in the Variable Data Length(VDL) 1 of the Ground Station Status and Position Message, the P2 message. The capability is also being used to obtain an alternate airbase to correlate to the Track Number Source (TNSC) that is stored in the flight plan.

4.9 Report Generation. The ISGCP has the capability of recording ATALARS messages and writing them to the line printer at the completion of the scenario. It also has the capability of presenting status and data screens at the System Control Console (SCC). The screens that are available list the status of an airbase, all non-Command and Control Air PPLI elements, all units that have been reported on via an Air PPLI message, a count of all the messages that have been sent between the ISGCP and GCUCP, and a log of all the ATALARS events that have taken place during the scenario.

TABLE IV

ISGCP AUTOMATIC MESSAGE PROCESSING

ISGCP INPUT MESSAGE PROCESSING	
MESSAGE RECIEVED	PROCESSING PERFORMED
M3-1 AIRCRAFT ASSIGNMENT	UPDATE FLIGHT PLANS AND DATABASE
J10.3 HANDOVER MESSAGE	ACKNOWLEDGE RECEIPT

ISGCP OUTPUT MESSAGE PROCESSING	
MESSAGE TRANSMITTED	PROCESSING PERFORMED
FLIGHT PLAN	CREATE AND TRANSMIT FLIGHT PLAN MESSAGE
M3-1 AIRCRAFT ASSIGNMENT	ACKNOWLEDGE RECEIPT

MESSAGE	DESCRIPTION	SIMULATION USE
J 2.2	AIR PPLI	AWACS, ATALARS ACFT (F-15s, ETC.)
J 3.2	AIR TRACK	NON JTIDS EQUIPPED ACFT (COMMERCIAL AIRLINES, HOSTILES, ETC)
J 3.5	LAND (GROUND) POINT/TRACK	SAM SITES
J 10.3	HANDOVER	TRANSFER CONTROL OF ACFT BETWEEN AWACS AND GCU
J 13.2	AIR PLATFORM & SYSTEM STATUS	PROVIDE PLATFORM STATUS OF J2.2 TYPE ELEMENTS
P 2	GROUND STATION POSITION AND STATUS REPORT	AIRBASES
FLIGHT PLAN	FLIGHT PLAN DATA	FLIGHT PLAN FOR ATALARS ACFT

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5.0 RESULTS AND RECOMMENDATIONS

To demonstrate each of the ATC algorithms developed under the ATALARS SBIR, a scenario depicting a conventional conflict in the NATO theatre consisting of 24 airborne elements was design. Each element was reported via an Air PPLI (J2.2) or track message (J3.2) and ten NATO airbases were reported via P2 messages. Voice callsigns and airbase status were reported using VDLs 1 & 5 to the P2 messages. The airborne elements were a mix of friendly, neutral, and hostile aircraft with those aircraft under ATALARS control visually identified by a subscripted "AC" for ATALARS control. Those friendly tracks not under ATALARS control but in voice contact with the ATALARS GCU were identified by a subscripted "AV" for ATALARS voice. Through the ISG, an operator or a member of the audience could alter the heading, airspeed, or altitude of a pre- scripted scenario element under ATALARS control. This provided the means to verify each of the ATC algorithms during the demonstration.

5.1 Results. The Proof of Concept demonstration showed conclusively that JTIDS messages could be employed in an ATC environment to resolve ATC-type conflicts and hazards. Specifically, the demonstration proved that through the use of existing TADIL-J PPLI messages, the track of an element under ATALARS control could be continuously monitored for path conformity, conflict avoidance, and hazard alert/avoidance. The GCU provided the operator with an audible and visual alert when deviations exceeded defined thresholds. Additionally, without operator action, algorithms in the GCU automatically determined the best solution to the ATC problem, and GCU-generated M3-1 assignment messages were automatically transmitted to each applicable aircraft resolving any deviation, conflict, or hazard.

5.1.1 Path Conformance Demonstration. To demonstrate the GCU's ability to detect an aircraft's deviation from its filed flight plan, a member of the audience selected at random an aircraft under ATALARS control. The aircraft's heading, altitude or speed was dynamically changed to force a violation of the path conformity lateral, vertical or time threshold. As soon as the threshold was exceeded, the GCU issued an alarm notifying the operator of a path conformance violation. The GCU then generated and transmitted an M3-1 assignment messages directing the aircraft back to its filed flight plan and ensured the new flight plan was conflict-free to its filed destination and hazard-free for the next thirty seconds. Once established on a new flight plan, hazard alerting guaranteed safe separation between an aircraft under ATALARS control and all other known traffic until hand-off to an arrival controller. To demonstrate complete GCU autonomy and proper algorithmic functionality, path conformance was demonstrated with the algorithm enabled and then disabled. With the path conformance algorithm disabled, no algorithms were invoked, no actions were taken by the GCU, and the affected aircraft would continue to deviate from its filed flight plan. With the algorithms enabled, the deviation was detected, reported, resolved, and the affected aircraft returned to its filed flight plan at or prior to its next waypoint.

5.1.2 Diversion Demonstration. An airbase was selected at random by a member of the audience and "closed". Upon the next transmission of its P2/VDL5, an alarm was issued

for each aircraft under ATALARS control with that airbase as its filed destination. This portion of the demonstration proved that the status of all reporting airfields was being continuously GCU-monitored and each affected element under ATALARS control would, independent of operator action, be automatically transmitted a GCU-constructed route of flight to the nearest suitable alternate immediately upon closure of its intended destination. Again, the new route of flight would be conflict free to the alternate airfield and hazard free for the next thirty seconds.

5.1.3 Conflict Avoidance Demonstration. The ability of the GCU to construct routes of flight around restricted airspace was demonstrated in conjunction with diversion. With the conflict avoidance algorithm disabled, a selected airbase was closed at such a time as to place an area of restricted airspace, defined with a J3.5 message, directly along a route generated from the aircraft's present position direct to the nearest suitable alternate. The airbase was then closed, the GCU constructed a route of flight, and the route of flight was then displayed to the operator. It penetrated restricted airspace. The scenario was repeated with the conflict avoidance algorithm enabled and the airbase was once again closed. The new flight plan was then displayed and the intended route of flight was around the restricted airspace. In most instances, the GCU constructed multi-segment routes of flight around restricted airspace to minimize flight time. In the remaining cases, a single point was sufficient to provide minimum flight time.

5.1.4 Hazard Avoidance. *Most significantly, the Proof of Concept scenario* demonstrated that a pre-scripted mid air collision would, prior to the involved aircraft reaching "near miss" criteria, be detected and averted with no operator intervention or action required. To demonstrate this, a point shortly after takeoff was selected and two aircraft were scripted to be at that point at the same time and at the same altitude. Again the demonstration was conducted with and without the hazard algorithm enabled. Without, the aircraft appeared to collide -- their positions became coincident. With the algorithm, one of the involved aircraft was directed to descend 1000 feet (twice the altitude threshold) when the hazard was detected. The display of tabular data at the Display Function Panel confirmed the altitude of the vectored aircraft decreasing at each reporting interval until it reached its assigned altitude. Additionally, the scenario demonstrated that an operator would not be notified a potential collision had been resolved until the aircraft had a minimum of a 1000 feet separation.

5.2 Recommendations. Though the Proof of Concept demonstration proved the operational utility of JTIDS messages in an ATC role, it became very apparent the current message set used by the Air Force lacked many of the operational parameters needed to convey data required by a aircrew to successfully complete their mission in an all-weather environment. Specifically, many of the items provided an aircrew via Automatic Terminal Information Service (ATIS) or Flight Information Publications (FLIP) were not available in the current message structure. Table V is a list of the types of data currently provided by ATIS or FLIP documents which are required for flight. The list is not intended to be exhaustive, but rather a subset of items that must be

TABLE V

ATALARS UNIQUE MESSAGE FIELDS

PHASE / DATA	DEPTARTURE	ENROUTE	ARRIVAL
PV	X		X
RVR	X		X
RSC	X		X
CEILING	X		X
RCR	X		X
PRECIP	X	X	X
W/V	X	X	X
ALTSTG	X	X	X
TURB	X	X	X
ICING	X	X	X
ALS	X	X	X
MEA		X	
MAA		X	
MRA	X	X	X
MCA	X	X	X
RWY	X		X
GS			X
TCH			X
DH			X
MDA			X
HAT			X
HAA			X
AFLD STAT	X	X	X
DEST	X	X	X
ALT	X	X	X
IAF			X
FAF			X
MAP			X
GSIA			X
FAS			X
TA			X
VDP			X
AFLD LTG	X		X

considered in an autonomous ATC environment and any further study of JTIDS message traffic for ATC functions.

The final recommendation for any future ATALARS exploration is one of processing requirements. Admittedly, the Proof of Concept scenario was, by design, on a greatly reduced scale with only 24 dynamic elements under ATALARS control. Even at this, given the complexity of the ATC algorithms and the need for continuous path, conflict, and hazard monitoring, the limits of the Ethernet LAN were approached. In an operational environment, ATALARS could conceivably support upwards of 1000 aircraft. To handle such a dense environment will require considerably greater process-

ing capabilities such as those provided by top-end, commercially-available workstations. As the need to demonstrate increased traffic handling capabilities increases, so does the need for increased operator interfaces. In a workstation environment, the operator can be provided with greater real-time control of participating elements thereby demonstrating even more conclusively the feasibility of secure, jam-resistant data links for autonomous control of a conventional conflict's air traffic control requirements.

6.0 LIST OF ACRONYMS

ACSI	Analysis & Computer Systems, Inc.
AFLD LTG	Airfield Lighting
AFLD STAT	Airfield Status
ALS	Approach Light System
ALT	Alternate
ALTSTG	Altimeter Setting
ATALARS	Automated Tactical Aircraft Launch and Recovery System
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
CA	Conflict Avoidance
CPU	Central Processing Unit
DEST	Destination
DH	Decision Height
DIV	Diversion
DPCP	Display Processor Computer Program
EJSE	Enhanced JTIDS System Exerciser
ETA	Estimated Time of Arrival
FAF	Final Approach Fix
FAS	Final Approach Speed
FLIP	Flight Information Publication
FPG	Flight Path Generation
GCUCP	Ground Control Unit Computer Program
GDT	Graphic Display Terminal
GS	Glide Slope
GSIA	Glide Slope Interception Altitude
HA	Hazard Alert
HAA	Height Above Airport
HAT	Height Above Touchdown
HR	Hazard Resolution
IAF	Initial Approach Fix
IAP	Initial Approach Point
ISG	Interactive Simulation Group
ISGCP	Interactive Simulation Group Computer Program
JTIDS	Joint Tactical Information Distribution System

LAN	Local Area Network
MAA	Maximum Authorized Altitude
MAP	Missed Approach Point
MCA	Minimum Crossing Altitude
MDA	Minimum Descent Altitude
MEA	Minimum Enroute Altitude
MRA	Minimum Reception Altitude
PCA	Path Conformance Alert
PPLI	Precise Participant Location and Identification
PRECIP	Precipitation
PV	Prevailing Visibility
RCR	Runway Condition Reading
RSC	Runway Surface Condition
RVR	Runway Visual Range
RWY	Runway
SA	Separation Assurance
SBIR	Small Business Innovation Research
SCC	System Control Console
STGCP	Simulation Tape Generation Computer Program
TA	Transition Altitude
TCH	Threshold Crossing Height
TNSC	Track Number Source
TURB	Turbulence
VDP	Visual Descent Point
VDL	Variable Data Length
W/V	Wind Velocity (Direction & Speed)

7.0 GLOSSARY OF ATC DEFINITIONS

ATALARS Control Area - An airspace region under control of an ATALARS GCU.

Conflict - An ATC state in which an aircraft will be redirected so as not to penetrate a restricted fixed airspace.

Diversion - The reassessment of a controlled aircraft's original filed destination to a new designated destination.

Hazard - An ATC state in which an aircraft is in such proximity to another aircraft as to require immediate action to avoid collision.

JTIDS Equipped Aircraft - Aircraft under control of an ATALARS GCU. In this JTIDS feasibility study, ATALARS aircraft are also JTIDS equipped.

Path Conformance - The assessment of a controlled aircraft's actual route of flight compared with its filed flight plan.

Restricted Airspace - Designated airspace that may not be penetrated by controlled aircraft without clearance from the controlling ATC agency. (Restricted airspace includes warning, danger, and prohibited areas).

Separation Assurance - The process of assuring that ATC states of hazard will not occur without a response from the controlling authority.